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The beat of social cognition: exploring the role of Heart Rate Variability as marker of mentalizing abilities

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Abstract

There is a long standing debate on the influence of physiological signals on social behavior. Recent studies suggested that heart rate variability (HRV) may be a marker of social cognitive processes. However, this evidence is preliminary and limited to laboratory studies. In this study 25 participants were assessed with a social cognition battery and asked to wear a wearable device measuring HRV for 6 consecutive days. The results showed that reduced HRV correlated with higher hostility attribution bias. However, no relationship was found between HRV and other social cognitive measures including facial emotion recognition, theory of mind or emotional intelligence. These results suggest that HRV may be linked to specific social cognitive processes requiring online emotional processing, in particular those related to social threat. These findings are discussed in the context of the neurovisceral integration model.

Keywords: mentalizing, heart rate variability, attribution bias, mHealth

Introduction

The neurovisceral integration model (Thayer et al., 2012) suggests that heart rate variability (HRV) should be treated as a complex indicator of brain activity rather than just a measure of heart function. This idea is substantiated by numerous studies showing an association between HRV variables and cognitive and emotional processes (e.g. Kreibig, 2010). Further, prefrontal autonomic control has been demonstrated with a series electrical brain stimulation experiments on prefrontal areas to exert an impact on respiration, blood pressure and a number other autonomic controlled functions (for a comprehensive review see Neafsey, 1990). HRV is claimed to index cortico-subcortical appraisal processes and has been linked with brain structures associated with threat perception including the ventromedial prefrontal cortex, the anterior cingulate cortex, the putamen and the amygdala (Thayer et al., 2012). Low HRV has also been hypothesized to be a biomarker of psychopathology - for example a population-based study found an association between illness onset HRV deregulation and depression prognosis after 10 years (Jandackova et al., 2016). A recent meta-analysis considering thirty-four studies concluded that HRV reduction is a robust finding in people with schizophrenia and advanced this biological abnormality as a possible endophenotype of the illness (Clamor et al., 2016). Large effect sizes were found both for high frequency HRV (Hedges' $g=-0.98$) and root mean square of successive interval differences (Hedges' $g=-0.91$), thus indicating lower vagal activity in patients compared to controls.

A common feature of mental health conditions is reduced social functioning. Recent research has started to link HRV deregulation to poor social interactions. A meta-analysis of experimental studies showed that reduced HRV is consistently present in individuals faced with negative social situations (Shahrestani et al., 2015). These studies simulate a social situation by requiring participants to read and immerse themselves in scenarios with negative emotions content. These include, for example, scenarios during which participant deliver a speech in front of a committee of a strangers (Shahrestani et al., 2015). The results of these studies converge in suggesting that HRV may be a marker of poor adaptation to stressful events (Shahrestani et al., 2015). Quintana et al. (2012) suggested that the HRV may be considered a physiological signal indicative of people's social cognitive proficiency. Accordingly, research in the field of psychopathology showed that HRV dysregulation is present alongside social cognitive deficits in individuals with schizophrenia (Jáuregui et al., 2011). Additionally, Gaebler et al. (2013) found lower HRV linked to the abnormal caudate nucleus activity in patients with social anxiety disorder while processing socio-emotional information.

While providing preliminary evidence to support the association between HRV and social cognitive processes, all these studies were limited by assessing HRV in laboratory settings. People's behavior is strongly situationally dependent, especially when it comes to social situations (Benz and Meier, 2008). The advent of mobile health technology (mHealth), allowing the "the delivery of healthcare services via mobile communication devices." (Torgan, 2009), provides the opportunity to assess social behavior in its natural context and study its peripheral nervous system parameters. Thus, this study aimed to explore the

relationship between HRV measures, recorded in everyday life situations, and social cognition. Numerous studies linked prefrontal activity with mentalizing processes (e.g. Denny et al., 2012) and suggested that HRV may be a marker of prefrontal-subcortical coupling (Thayer et al., 2012). We therefore hypothesize to detect an association between HRV and mentalizing abilities.

Methods

Participants

Participants were recruited through local advertisement in south London, UK. To be eligible volunteers had to be aged between 18-55 years, had no history of mental, substance dependence or neurological disorders, no learning disability, not taking psychotropic medication, and good command of English language.

Procedure

Participants were screened over the phone for the study inclusion and exclusion criteria. Mental illness history was assessed using the M.I.N.I. International Neuropsychiatric Interview (Sheehan et al., 1998). All eligible participants met with a study researcher and received instruction on how to operate the mHealth device. During this first meeting the researcher collected demographic information and the social cognition measures. Participants were asked to wear the mHealth device during their normal day-to-day activities up to 6 consecutive days but asked to remove it when: doing physical exercises (e.g. gym); there was a risk of the device being in contact with water (e.g. washing) or sleeping at night. Participants met the researcher after the 6th day, returned the device and were debriefed. The study research protocol was reviewed and approved by King's College London ethic committee. All participants signed a written consent form and received compensation for their time.

HRV measurement

HRV was measured with Empatica E3 wristbands. The measurement of the mean time elapsing between two consecutive R waves data were extracted from the photoplethysmographic recording with Empatica Algorithm 1 and 2 (see Garbarino et al., 2014 for the detailed information on sensor and Empatica, 2015 and Tognetti et al., 2015 for information on the algorithms). Data was further processed with Kubios HRV after visual inspection of the inter-beat interval data (Tarvainen et al., 2014). Standard deviation of all normal RR intervals (SDNN) and root mean square of the successive differences of RR intervals (RMSSD) were extracted with standard algorithms implemented in Kubios software (Thayer et al., 2012).

Social cognition measures

Emotional processing was assessed with Facial Emotion Identification Test (FEIT; Kerr and Neale, 1993). In this task participants are asked to identify which of six emotions words best describe a still face picture. Emotional intelligence was assessed by The Trait Emotional Intelligence Questionnaire (Cooper and Petrides, 2010). The Ambiguous Intentions Hostility Questionnaire (AIHQ; Combs et al., 2013) was chosen as a measure of attribution biases in participants. In line with results of previous studies in the general population we used the ambiguous vignettes only (Combs et al., 2013). Finally, Theory of Mind processes were assessed with the Hinting Task (Corcoran et al., 1995).

Analysis

For this study we decided to analyze the longest continuous HRV recording period available for all participants (i.e. 8 hours). This is because a longer period provides some variability in the activity and allows treating HRV as a global measure of neural integrity, rather than an indicator of situational behavior.

Pearson correlation coefficient was used to assess the association between HRV variables and main score of each task. Partial correlations were used to control for the effect of moderating variables (e.g. age). For the AIHQ we analyzed scores for each type of biases. As previous research found age to be associated with HRV, we considered this variable as a covariate using partial correlations. Statistical threshold was set at $p < 0.05$ two tails.

Results

Approximately one third of the participants had 8 hours long recordings from three or more days. The average length of the longest continuous recording was 14.4 ± 7.5 hrs suggesting that participants were occasionally taking the device off. To make the comparison between samples balanced, we decided to use the data from the first chronologically recording of 8hrs. All the 25 participants recruited had at least one 8hrs recording period.

Basic descriptive statistics of the variables reported in the study are shown in a Table 1. Age was negatively associated with both SDNN ($r = -.43$ $p = .030$) and RMSSD ($r = -.43$ $p = .032$). After partialling out the effect of age we found a significant correlations between Hostility Bias and both SDNN ($r_p = -.41$ $p = .046$) and RMSSD ($r_p = -.46$ $p = .024$). Furthermore, a trend towards significance was observed for correlation between RMSSD and AIHQ Blame Score ($r_p = -.37$ $p = .072$) and between SDNN and AIHQ Aggression Score ($r_p = -.40$ $p = .056$). HRV parameters did not correlate with the remaining social cognition measures.

Discussion

This study examined the relationship between HRV measures, recorded in a naturalistic setting, and social cognitive domains. The results showed an association

between Hostility Bias and HRV measures. However, HRV was not associated with other domains of social cognition.

Similarly to a previous study, our results linked lower mental state attribution scores with reduced HRV (Quintana et al., 2012). Mental attribution requires both socioemotional processing and mentalizing, thus in the case of complex social interactions it may be possible that HRV reduction may influence both processes rather than either. This is however a speculation as to date there is no data in support of this. In a study examining HRV and brain activity while participants performed a social evaluative threat task, it was found that this process is regulated via two cortico-subcortical pathways linking sub-regions of medial prefrontal cortex with heart rate (Wager et al., 2009). In another study, males with medial prefrontal cortex (mPFC) lesions rated threat higher in socially challenging situations and had lower HRV compared to non-mPFC brain damaged patients and healthy control groups (Buchanan et al., 2010). These results further support the view that HRV and attributional bias for hostile intentions may be linked to reduced prefrontal inhibition over subcortical activity, which may lead to increased threat perception (Thayer et al., 2012).

Our results are congruent with previous studies examining the relationship between HRV and attribution style in the general population. Higher HRV was observed to be associated with a more balanced attributional style (Grossman et al., 2016). In another study, which has used social situation vignettes, lower HRV was associated with higher blame attribution, but only if the action was framed as intentional (León et al., 2009). These studies were, however, limited by the fact that social situations were modelled by experimental tasks which may reflect only partially real life situations. Here, we collected HRV during participants' everyday life. This provides a rationale to support the role of HRV as a proxy for real life aberrant processing of threat associated with social interactions.

The large majority of mental health conditions are associated with social cognition difficulties and these difficulties have been found to predict long term functioning and social function outcomes (Billeke and Aboitiz, 2013). Monitoring HRV parameters using mHealth devices may offer a practical and cost-effective solution for assessing processes associated with recovery progress or symptom relapse. However, some limitations apply to the results of this study.

Despite we asked participants to wear the mHealth devices for 6 days memory capacity could hold approximately 30 hours of recording, thus for most participants recordings were available for first three days. To ensure that the time period used in the analysis included social activities, we collected information of social functioning levels from all participants using a semi structured interview (Cella et al., 2016). This was done to ascertain that participants would regularly engage with various activities, including socializing, during their everyday life. All participants spent significant portions of their weekly activities socializing ($M=36 \pm 29$ hours). As participants reported that the week of recording was similar to their average week we could assume that participants were exposed to some social activities during the recording. Future studies should aim to collect more precise information on the level, quality and type of social activities as these may have a different impact on physiological parameters. Further, all of the social cognitive measures

used in this study were paper-pencil based tasks. Future studies should also include social simulation paradigms (Shahrestani et al., 2015) and tasks aimed to assess the impact of contextual processing on social decision making (e.g. by the means multiplayer economic games (King-Casas and Chiu, 2012).

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References

1. Benz, M., Meier, S. (2008). Do people behave in experiments as in the field?—evidence from donations. *Experimental economics*, 11, 268-281.
2. Billeke, P., Aboitiz, F. (2013). Social cognition in schizophrenia: from social stimuli processing to social engagement. *Frontiers in Psychiatry*, doi: 10.3389/fpsyt.2013.00004
3. Buchanan, T. W., Driscoll, D., Mowrer, S. M., Sollers, J. J., Thayer, J. F., Kirschbaum, C., Tranel, D. (2010). Medial prefrontal cortex damage affects physiological and psychological stress responses differently in men and women. *Psychoneuroendocrinology*, 35, 56-66.
4. Cella, M., Edwards, C., Wykes, T. (2016). A question of time: A study of time use in people with schizophrenia. *Schizophrenia Research*, doi: 10.1016/j.schres.2016.06.033.
5. Clamor, A., Lincoln, T. M., Thayer, J. F., Koenig, J. (2016). Resting vagal activity in schizophrenia: meta-analysis of heart rate variability as a potential endophenotype. *The British Journal of Psychiatry*, 208, 9-16.
6. Combs, D. R., Finn, J. A., Wohlfahrt, W., Penn, D. L., Basso, M. R. (2013). Social cognition and social functioning in nonclinical paranoia. *Cognitive neuropsychiatry*, 18, 531-548.
7. Cooper, A., Petrides, K. V. (2010). A psychometric analysis of the Trait Emotional Intelligence Questionnaire-Short Form (TEIQue-SF) using Item Response Theory. *Journal of Personality Assessment*, 92, 449-457
8. Corcoran, R., Mercer, G., Frith, C. D. (1995). Schizophrenia, symptomatology and social inference: investigating “theory of mind” in people with schizophrenia. *Schizophrenia research*, 17, 5-13.
9. Denny, B. T., Kober, H., Wager, T. D., Ochsner, K. N. (2012). A meta-analysis of functional neuroimaging studies of self-and other judgments reveals a spatial

gradient for mentalizing in medial prefrontal cortex. *Journal of cognitive Neuroscience*, 24, 1742-1752.

10. Empatica (2015). How is IBI.csv obtained? Retrieved from: <https://support.empatica.com/hc/en-us/articles/201912319-How-is-IBI-csv-obtained->
11. Gaebler, M., Daniels, J. K., Lamke, J. P., Fydrich, T., Walter, H. (2013). Heart rate variability and its neural correlates during emotional face processing in social anxiety disorder. *Biological psychology*, 94, 319-330.
12. Garbarino, M., Lai, M., Bender, D., Picard, R. W., Tognetti, S. (2014, November). Empatica E3—A wearable wireless multi-sensor device for real-time computerized biofeedback and data acquisition. In *Wireless Mobile Communication and Healthcare (Mobihealth), 2014 EAI 4th International Conference on* (pp. 39-42). IEEE.
13. Grossman, I., Sahdra, B.K., Ciarrochi, J. (2016). A Heart and A Mind: Self-distancing Facilitates the Association Between Heart Rate Variability, and Wise Reasoning. *Frontiers in Behavioral Neuroscience*, <http://dx.doi.org/10.3389/fnbeh.2016.00068>
14. Jandackova, V. K., Britton, A., Malik, M., Steptoe, A. (2016). Heart rate variability and depressive symptoms: a cross-lagged analysis over a 10-year period in the Whitehall II study. *Psychological medicine*, 1-11.
15. Jáuregui, O. I., Costanzo, E. Y., de Achával, D., Villarreal, M. F., Chu, E., Mora, M. C., Vigo, D.E., et al. (2011). Autonomic nervous system activation during social cognition tasks in patients with schizophrenia and their unaffected relatives. *Cognitive and Behavioral Neurology*, 24, 194-203.
16. Kerr, S. L., Neale, J. M. (1993). Emotion perception in schizophrenia: specific deficit or further evidence of generalized poor performance?. *Journal of abnormal psychology*, 102, 312.
17. King-Casas, B., & Chiu, P. H. (2012). Understanding interpersonal function in psychiatric illness through multiplayer economic games. *Biological psychiatry*, 72(2), 119-125.
18. Kreibig, S.D. (2010). Autonomic nervous system activity in emotion: A review. *Biological psychology*, 84, 394-421.
19. León, I., Hernández, J. A., Rodríguez, S., Vila, J. (2009). When head is tempered by heart: Heart rate variability modulates perception of other-blame reducing anger. *Motivation and Emotion*, 33, 1-9.
20. Neafsey, E. J. (1991). Prefrontal cortical control of the autonomic nervous system: anatomical and physiological observations. *Progress in brain research*, 85, 147-166.
21. Quintana, D. S., Guastella, A. J., Outhred, T., Hickie, I. B., Kemp, A. H. (2012). Heart rate variability is associated with emotion recognition: direct evidence for a relationship between the autonomic nervous system and social cognition. *International Journal of Psychophysiology*, 86, 168-172.

22. Shahrestani, S., Stewart, E. M., Quintana, D. S., Hickie, I. B., Guastella, A. J. (2015). Heart rate variability during adolescent and adult social interactions: A meta-analysis. *Biological psychology*, 105, 43-50.
23. Sheehan, D. V., Lecrubier, Y., Sheehan, K. H., Amorim, P., Janavs, J., Weiller, E., Hergueta, T., Baker, R., Dubbar, G.C. (1998). The Mini-International Neuropsychiatric Interview (MINI): the development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. *Journal of Clinical Psychiatry*, 59 Suppl 20: 22-33.
24. Tarvainen, M. P., Niskanen, J. P., Lipponen, J. A., Ranta-Aho, P. O., Karjalainen, P. A. (2014). Kubios HRV—heart rate variability analysis software. *Computer methods and programs in biomedicine*, 113, 210-220.
25. Thayer, J. F., Åhs, F., Fredrikson, M., Sollers, J. J., Wager, T. D. (2012). A meta-analysis of heart rate variability and neuroimaging studies: implications for heart rate variability as a marker of stress and health. *Neuroscience & Biobehavioral Reviews*, 36, 747-756.
26. Tognetti, S., Cenci, I., Resnati, D., Garbarino, M., & Lai, M. (2015). U.S. Patent No. 20,150,327,787. Washington, DC: U.S. Patent and Trademark Office.
27. Torgan, C. (2009). The mHealth Summit: Local & Global Converge. Retrieved from <http://caroltorgan.com/mhealth-summit/>
28. Wager, T. D., van Ast, V. A., Hughes, B. L., Davidson, M. L., Lindquist, M. A., Ochsner, K. N. (2009). Brain mediators of cardiovascular responses to social threat, part II: Prefrontal-subcortical pathways and relationship with anxiety. *Neuroimage*, 47, 836-851.